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# Development of a gesture learning environment for novices' erhu bow strokes

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## Abstract

This paper describes the development of a gesture learning environment for a novices' erhu bow strokes, which diagnoses bow strokes by using magnetic position sensors and feedback errors by showing bow strokes on virtual 3D space and coloring. The system has two windows: bow strokes window for visualization of bow strokes and feedback errors and score window for diagnosing bow strokes along score. In addition, we evaluated the system by Likert scale questionnaire survey. The result of questionnaire indicates that the novice learner was able to recognize and improved errors of bow strokes. It was difficult for novice learners to do that by using conventional method. Moreover, our experiment shows the system useful to learn gesture of bow strokes.

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**Keywords:** Magnetic position sensors; Bowed string instruments; Skill; Learning environment; Gesture of bow strokes

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## 1. Introduction

Generally, to learn skills for playing instruments is achieved by means of taking a lesson, practicing by self-learning, referring to a study-aid book, and so on. In case of self-learning, the novices give up acquiring skills because they get into a wrong habit, don't understand how to play instruments and don't make progress. Particularly, the bowed string instruments (e.g. the violin, the cello, and the erhu) have many parameters to control. The

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parameters are the finger positions, the pressures of pressing strings, the gesture, the speed, the acceleration, and the angle of bow strokes. So, it is difficult for the novices to play with accurate pitches. Therefore, if we develop a learning environment for playing the bowed string instruments, these problems will be solved. Because of these backgrounds, we aimed to develop a learning environment for playing the bowed string instruments. In this paper, we propose a design of a gesture learning environment for novices' erhu bow strokes.

## 2. Related works

### 2.1. Learning environment of musical skills

Recently, there are many studies about analysis of skills and the learning environment because of progress of sensors and computers performances (e.g. the piano<sup>1,2,3</sup>, the guitar<sup>4,5</sup>, the drum<sup>6,7,8,9</sup>, the violin<sup>10,11</sup>). Although there are many studies about musical skills, there is no study about the erhu except for our studies.

In case of the bowed string instruments, there are many studies about analysis of playing the violin<sup>12,13,14,15,16,17,18,19</sup>. Although there are many studies by using various methods, these studies aim to analysis of playing the violin. In this paper, we aim to develop a learning environment ahead of analysis. Moreover, there is a study about pitch training system for violin learners<sup>20</sup>. However, this pitch training system does not diagnose learner's gesture parameters and pressure parameters, but diagnoses only sound pitches. Therefore, the novice learner cannot identify the cause of pitch errors. So, we aimed to develop learning environment for novice learner to understand why pitch errors caused.

### 2.2. Our previous works

We have aimed to develop a learning environment for playing the bowed string instruments and have developed learning environment. Firstly, we have analyzed novice players' parameters during playing a bowed string instrument. Specifically, we analyzed erhu playing parameters by novice players<sup>21</sup>. As the results of the analysis, novices need supports of finger positions, bow motions, bow speeds, bow accelerations, and bow angles. The sounds depend on these parameters. A novice doesn't understand the reasons why the sounds aren't correct because there are many parameters to control. Therefore, a novice needs a learning support environment for controlling each parameter. Secondly, we tried to assist a learner to control finger positions. We developed a learning environment regarding finger position on strings<sup>22</sup>. Figure 1 shows a screen shot of our previous system. By making evaluation experiment, we found the system is useful for a novice to learn finger position on strings. Therefore, we aim to develop a learning environment for novice learner to accurate gesture of erhu bow strokes, subsequently to finger position.

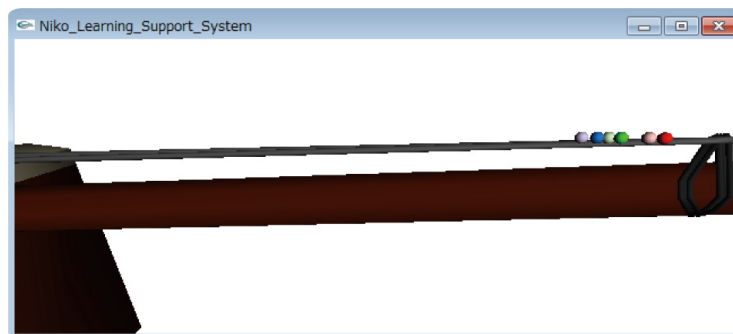


Fig. 1. Screen shot of our previous system.

### 3. Instruments choice

#### 3.1. The erhu

We have chosen the erhu in bowed string instruments. Figure 2(a) shows an erhu. Figure 2(b) shows left hand during playing the erhu. Figure 2(c) shows right hand during playing the erhu.

There is a reason that we have chosen the erhu in bowed string instruments. It is two-stringed instrument. Because of two-stringed instrument, a learner only needs to judge which string he/she touches in those two strings with a bow. In case of violin, a learner needs to judge which string he/she touches in four strings with a bow. Therefore, his/her hand and finger motions are very complicated. Therefore, it is very difficult for the novice learner to learn the skills.



Fig. 2. (a) The erhu; (b) Left hand during playing the erhu; (c) Right hand during playing the erhu.

#### 3.2. How to play

How to play the erhu is as follows. Left fingers press strings with pitches as Figure 2(b). Then, it needs accurate finger position skill. A pitch error reflects a finger position error directly because the erhu has no border between pitches. Moreover, if the finger pressures are too weak, the learner cannot play clear sounds. On the other hand, right hand holds a bow from underneath as Figure 2(c). Then, right index finger is attached to the wood part and right middle finger and ring finger control hair tension of the bow. A learner plays sounds by moving the bow between right and left, by the frictions between the bow and the strings. Loudness and expression of sounds depend on pressures between the bow and the strings, moving speed of the bow, and how to move the bow.

#### 3.3. Bad example of erhu bow strokes

Figure 3(a), Figure 3(b) and Figure 3(c) show bad examples of erhu bow strokes. The gesture of erhu bow strokes should be parallel to the ground. Therefore, Figure 3(a) is a bad example because the gesture of erhu bow strokes are not parallel to the ground. Moreover, the bow strokes should not leave the resonator body. Therefore, Figure 3(b) is the bad example because the bow strokes leave the resonator body. Furthermore, the gesture of erhu bow strokes should be parallel to the surface of the body. Therefore, Figure 3(c) is the bad example because the bow strokes are not parallel to the surface of the body. Based on the above, we aim to develop the system that makes the novice learner being aware of these bad examples and learning accurate gesture of erhu bow strokes.



Fig. 3. (a) Not parallel to the ground; (b) The bow strokes leave the resonator body; (c) Not parallel to the surface of the body.

## 4. System design

### 4.1. Magnetic position sensors LIBERTY

LIBERTY is magnetic position sensors developed by Polhemus Inc. A transmitter and up to 16 receivers are connected to a main unit for use. Figure 4(a) shows magnetic position sensor LIBERTY. Figure 4(b) shows transmitter of LIBERTY. Figure 4(c) shows receivers of LIBERTY. A transmitter generates magnetic fields which have three directions by passing an electric current in turn through coils around three axes. Receivers also have coils around three axes. When a magnetic field is generated by the transmitter, an induced electric current is generated in the receivers. Then, position and orientation of each receiver is measured by this amperage. This measured data is transmitted to a connected PC as ASCII or binary data. Liberty is connected with PC through USB ports or serial ports. The reason why we choose LIBERTY as a motion tracking sensor is that we need to use real-time 3D tracking data for real-time visualization and real-time diagnosis.



Fig. 4. (a) Magnetic position sensors LIBERTY; (b) Transmitter of LIBERTY; (c) Receivers of LIBERTY.

### 4.2. System composition

Figure 5 shows system composition. The system consists of a PC, a magnetic position sensor LIBERTY and an erhu. The erhu is equipped with a transmitter and receivers of LIBERTY. Figure 6 shows the erhu is equipped with a transmitter and receivers of LIBERTY. We equipped the erhu with a transmitter and receivers for measuring gesture of erhu bow strokes as Figure 6. The system diagnoses learner's gesture of erhu bow strokes by using data measured by the receivers. The learner learns playing skills about bow strokes by using this information.

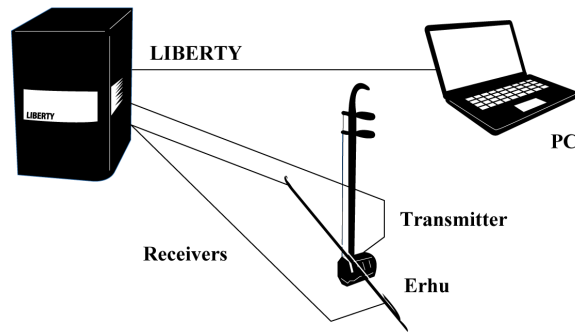


Fig. 5. System composition.



Fig. 6. The erhu equipped with a transmitter and receivers of LIBERTY.

#### 4.3. System screen

This system has two windows on screen. One is bow strokes window for visualization of bow strokes and feedback bow strokes errors. The other is score window for diagnosing bow strokes during playing the erhu.

#### 4.4. Bow strokes window

Figure 7 shows bow strokes window. It shows bow strokes with virtual erhu model in the virtual 3D space. This bow strokes represent learner's bow strokes measured by magnetic position sensors on real-time. The learner's playing is diagnosed by the system. The results of diagnosis are represented as following. During accurate bow strokes, they are colored green as Figure 8. If bow strokes are not parallel to the ground (over 10 degrees), they are colored red or blue. Figure 8(a) and Figure 8(b) show bow strokes window while bow strokes are not parallel to the ground. If bow strokes are not parallel to the surface of the body (over 10 degrees), they are colored pink or orange. Figure 9(a) and Figure 9(b) show bow strokes window while bow strokes are not parallel to the surface of the body. If bow strokes leave the resonator body (over 0.5 inch), they are colored black. Figure10 shows bow strokes window while bow strokes leave the resonator body. Viewpoint in the virtual 3D space is changeable freely. The learner can recognize bow strokes errors by watching bow strokes window.

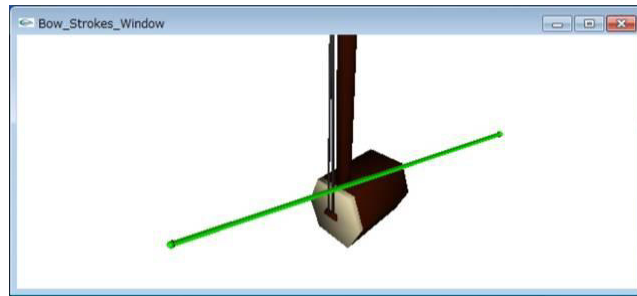


Fig. 7. Bow strokes window.

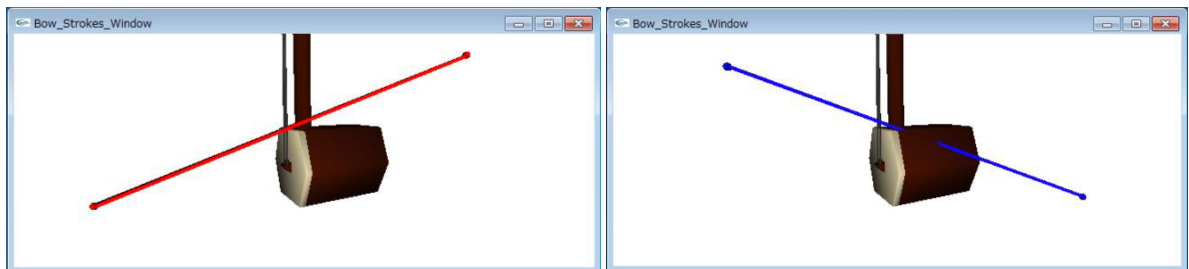


Fig. 8. While bow strokes are not parallel to the ground (a) left down; (b) right down.

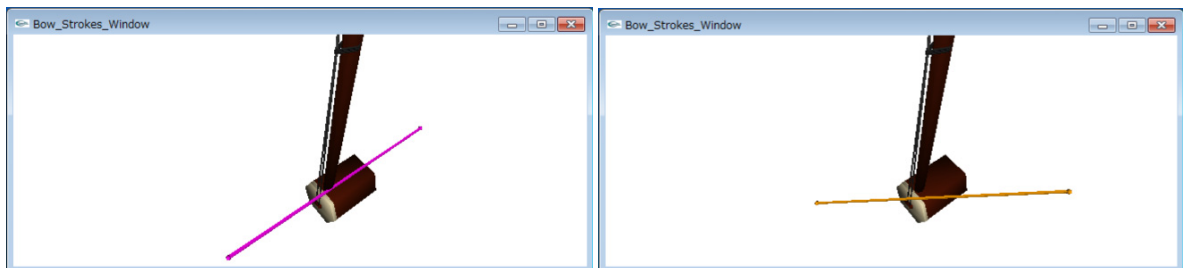


Fig. 9. While bow strokes are not parallel to the surface of the body (a) left is an acute angle; (b) right is acute angle.

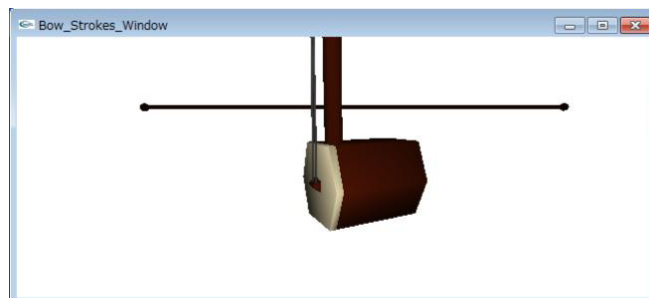


Fig. 10. While bow strokes leave the resonator body.

#### 4.5. Score window

Figure 11 shows score window. It shows score of the music, current diagnosing point on the score, and results of diagnosing. The current diagnosing point is shown by a black line, and it moves along the score. A learner plays the erhu by synchronizing the current playing note with the current note on the black line. The results of diagnosis are indicated under the notes as colored figures that correspond to the representation in bow strokes window. The learner can recognize where he/she made errors of bow strokes and how to correct his/her errors.



Fig. 11. Score window.

### 5. Evaluation

#### 5.1. Experiment method

Figure 12 shows evaluation experiment outline. We experimented with eight novices regarding playing the erhu who are students in their early twenties. Firstly we divided the subjects into two groups; group A and group B for taking counterbalance. After that, we explained how to play the erhu in 10 minutes. After the explanation, the subjects in group A trained himself/herself for 10 minutes by watching DVD. On the other hand the subjects in group B trained himself/herself for 10 minutes by using the system. After that we conducted the common questionnaire survey to both groups. After the common questionnaire survey, the subjects in group A trained himself/herself for 10 minutes by using the system. On the other hand, the subjects in group B trained himself/herself for 10 minutes by watching DVD. After that, we conducted same common questionnaire survey as before and other questionnaire survey about the system to both group.

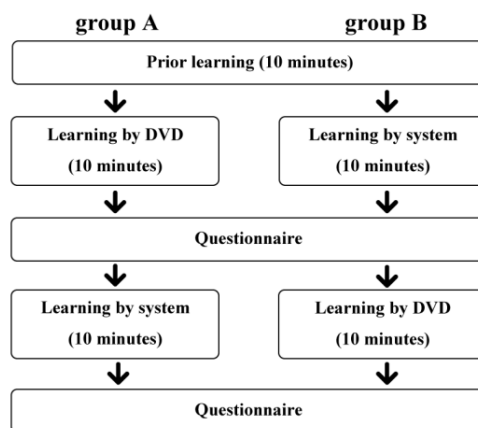


Fig. 12. Evaluation experiment outline.



### 5.2. Contents of questionnaire

We evaluated whether or not subjects acquired awareness of accurate bow strokes and how effective each method was for learning gesture of bow strokes by questionnaire survey. The questionnaire was five levels evaluations by Likert scale. Table 1 shows contents of questionnaire we conducted twice. Table 2 shows contents of questionnaire about the system, which was needed to evaluate system usability and efficiency of each function. The five levels by Likert scale were as follows

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

Table 1. Contents of the common questionnaire.

Content of questionnaire	
A	You have recognized errors of bow strokes.
B	You have improved gesture of bow strokes.
C	You will acquire playing skill about gesture of bow strokes in the future.
D	You have learned efficiently.
E	You will learn continuously in the future.
F	You have increased your motivation of learning.
G	This method is useful for learn gesture of bow strokes.

Table 2. Contents of the questionnaire about the system.

Content of questionnaire	
H	System is user-friendly.
I	It is useful to show your bow strokes.
J	It is useful to feedback about bow strokes errors by using color.
K	It is useful to feedback about bow strokes errors on score window.
L	Sensors have not interfered with your playing.

### 5.3. Results of experiment

Table 3 shows the result of the common questionnaire survey. Table 4 shows the result of the questionnaire about the system. The value of tables is the total of each level in Likert scale on each question. The question A to G in Table 3 match the question A to G in Table 1. The question H to L in Table 4 match the question H to L in Table 2.

In case of question A, mode value of the system is 5 and that of DVD is 2. This result showed novices was able to recognize errors of bow strokes by using the system. It was difficult by using conventional method. In case of question B, mode value of the system is 5 and DVD is 1 and 3. This result showed novices can improve gesture of bow strokes. It was difficult by using conventional method. From the above, the novice was able to recognize and improve errors of bow strokes by using the system.

The result in Table 4 shows each function was useful for learning gesture of bow strokes. However, there were free descriptions that said “it is difficult for a learner who use the system first time to remember mapping of colors with errors.”



Table 3. Result of the common questionnaire.

	System					DVD				
	1	2	3	4	5	1	2	3	4	5
A	0	0	0	3	5	1	5	1	1	0
B	0	0	1	3	4	3	2	3	0	0
C	0	0	1	3	4	1	6	1	0	0
D	0	0	3	2	3	2	5	1	0	0
E	0	0	0	7	1	1	1	5	1	0
F	0	0	4	1	3	2	1	4	1	0
G	0	0	1	2	5	1	4	2	1	0

Table 4. Result of the questionnaire about the system.

	1	2	3	4	5
H	0	0	0	5	3
I	0	0	1	1	6
J	0	0	2	4	2
K	0	0	0	4	4
L	0	0	1	1	6

## 6. Future work

We found that there was still room for improvement in this system. Therefore, we will improve the system based on the points of improvement by free description about the system.

In the future, we will combine this system with our previous system regarding finger position. Both systems use LIBERTY. Therefore, this system and our previous system can be integrated. By integrating both systems, the novice learner can recognize errors finger position and bow strokes at the same time.

We use position and orientation data of LIBERTY on real-time and record part of data. We will develop record and play back function. By using play back function, the novice learner will be able to get more awareness.

## 7. Conclusion

In this paper, we designed and developed a gesture learning environment for novices' erhu bow strokes, which diagnosed bow strokes by using magnetic position sensors and gave a learner error feedback by coloring. The system has two windows, bow strokes window for visualization of bow strokes and error feedback, score window for diagnosing finger position along score. In addition, we evaluated the system by Likert scale questionnaire survey. The result of questionnaire survey indicated that the novice learner was able to recognize and improve errors of bow strokes. It was difficult for novice learners by using conventional method. Moreover we found the system useful to learn gesture of bow strokes. Therefore, we have achieved the aim.

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